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(54) Abstract Title
Hybrid vehicle powertrain control

(57) A motor vehicle has an electric motor 31 to supply an auxiliary source of power to a gearbox output shaft 21 through an auxiliary gear train and a first auxiliary clutch 35 when a ratio change is being effected. In this way, a continuous supply of power to the drive wheels 26, 27 is obtained. A second auxiliary clutch 36 can supply power to the gearbox input shaft 14 to assist starting from rest and reduce the power dissipated in the drive clutch 12.

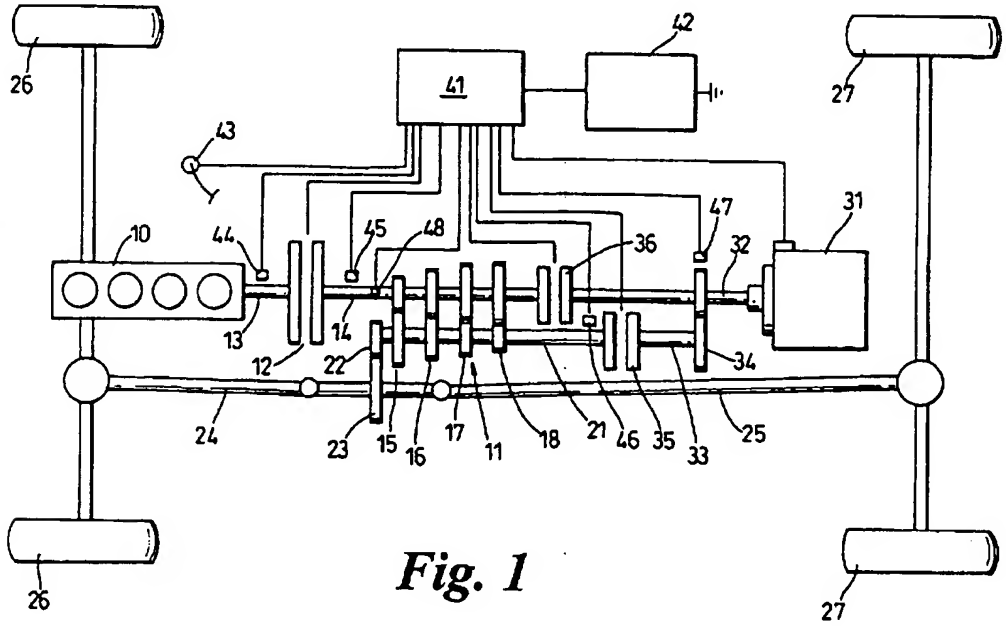

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

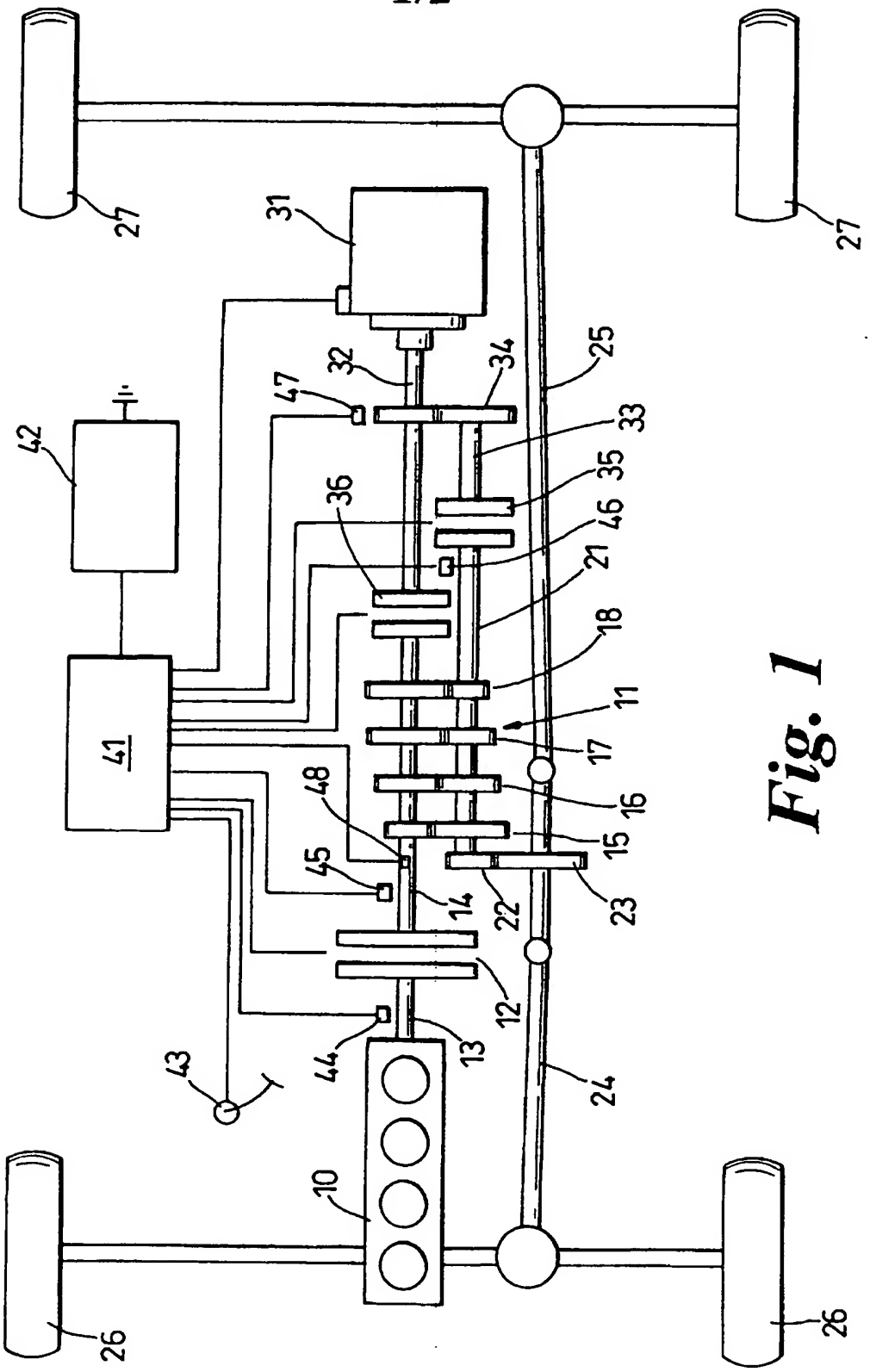
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Fig. 1

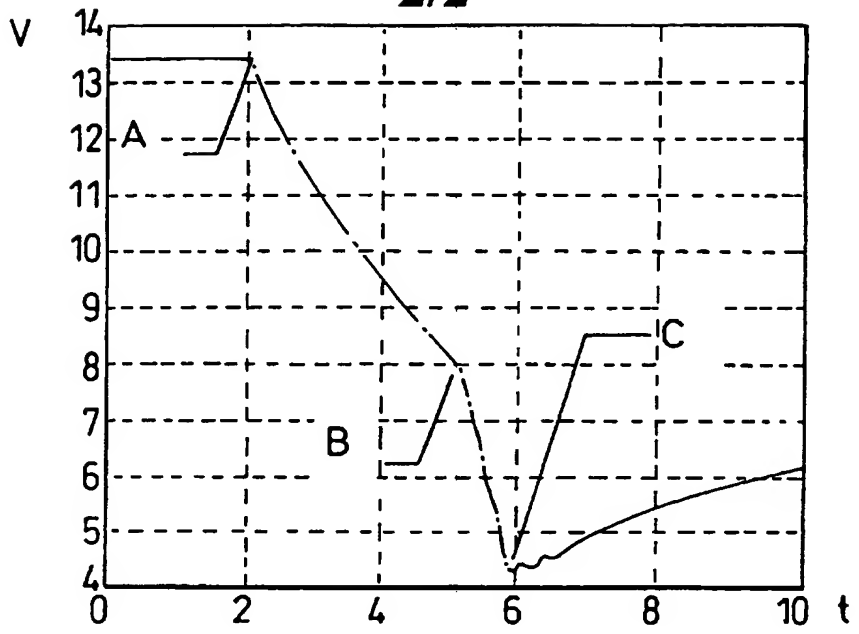

Fig. 2

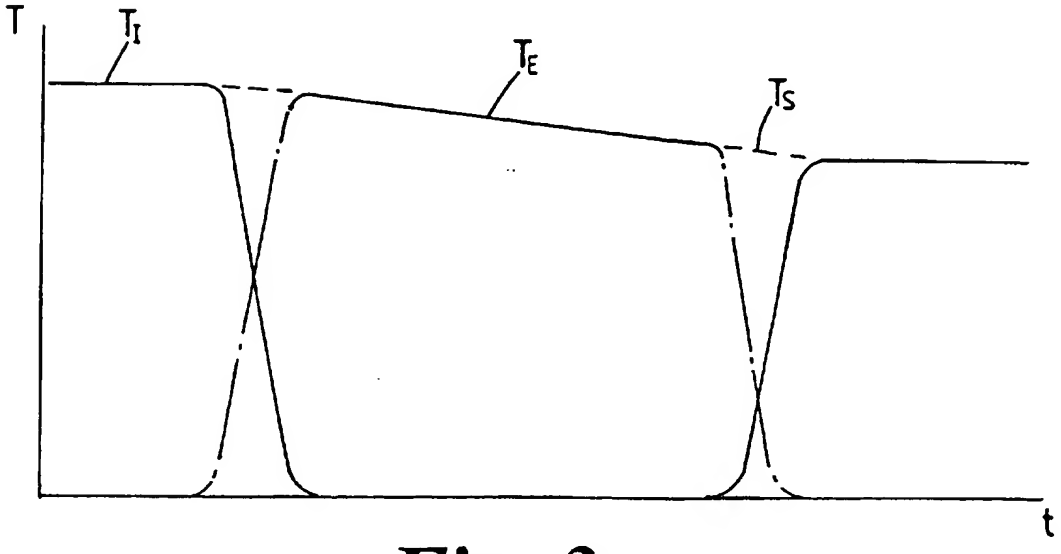

Fig. 3

A Motor Vehicle

This invention relates to a motor vehicle and in particular to a motor vehicle having a multi-speed gearbox with pre-determined ratios.

It is a problem with most motor vehicles having a multi-speed gearbox that when changing from one ratio to the next in either direction drive is momentarily lost. This can be particularly disadvantageous if the motor vehicle is negotiating a corner, overtaking or climbing a steep hill.

It is an object of this invention to provide a motor vehicle that alleviates the above disadvantage.

According to the invention there is provided a motor vehicle having an engine, a transmission system to transmit drive from the engine to one or more driven road wheels and a drive clutch interposed between the engine and the transmission system to selectively engage drive therebetween, the transmission system having a multi-speed gearbox including constant mesh gear trains each comprising a pair of gears, one gear of each pair being mounted on a driving shaft and the other of each pair being mounted a driven shaft to provide a number of gearbox ratios, the driving shaft being operatively connected to the drive clutch and the driven shaft being operatively connected to the or each road wheel, the motor vehicle further comprising an electric motor drivably connected to the driven shaft to provide a driving effort to the transmission system at least when the gearbox is changing gear so as to provide a continuous supply of power to the or each driven road wheel.

Conveniently the electric motor is selectively connected to the driven shaft by a first auxiliary clutch.

The electric motor may be selectively connected to the driving shaft by a second auxiliary clutch. This provides an alternative path for power supplied by the electric motor if the electric motor is used at times other than during gear changing.

The electric motor may be connected to the first auxiliary clutch by an auxiliary gear train. This can provide a more convenient gear ratio in the drive from the electric motor than if the electric motor is directly connected to the gearbox driven shaft.

The electric motor may be arranged to provide a driving effort to the or each driving wheel when the motor vehicle is starting from rest to assist with engagement of the drive clutch, in which case, when the motor vehicle is starting from rest, the electric motor may be connected to the driving shaft by the second auxiliary clutch..

An anti-lock braking system may be provided to prevent skidding of the road wheels and the electric motor used to supply additional power to the or each driven road wheel in the event of wheel lock being sensed.

The invention will now be described by way of example with reference to the accompanying drawings of which:-

Fig.1 is a schematic view of a motor vehicle according to the invention;

Fig.2 is a graph of motor vehicle speed against time during an uphill gear change for a motor vehicle in which the present invention is not operable; and

Fig.3 is a graph of gearbox output torque against time during a gear change in a vehicle as shown in Fig.1.

With reference to Fig.1, a motor vehicle has an internal combustion engine 10 and a transmission system which includes a multi-speed gearbox 12. The engine 10 drives the gearbox 11 through a drive clutch 12 mounted on an engine crankshaft 13, the drive clutch 12 selectively providing drive to an input shaft 14 of the gearbox 11. The gearbox 11 houses first, second, third and fourth forward ratio constant mesh gear trains 15, 16, 17, and 18 respectively, each gear train comprising a pair of gears, one gear of each pair being fixed to or integral with a driving shaft in the form of the input shaft 14 and the other of each pair being mounted on a driven shaft in the form of an output shaft 21 for selection by synchromesh clutches. A conventional selector mechanism (not shown) is used to select the synchromesh.

The transmission system also includes a pair of transfer gears 22, 23 which transmit drive from the output shaft 21 to front and rear propshafts 24, 25 which connect the gearbox 11 to front driven wheels 26 and rear driven wheels 27.

An electric motor 31 is connected to an auxiliary drive shaft 32 which also drives a secondary drive shaft 33 through an auxiliary gear train 34. The secondary drive shaft 33 provides a drive to a first auxiliary clutch 35 that can be used to connect the electric motor 31 to the gearbox output shaft 21. The auxiliary drive shaft 32 also provides a drive to a second auxiliary clutch 36 that can be used to connect the electric motor 31 to the gearbox input shaft 14.

Control of the drive clutch 12 and the auxiliary clutches 35, 36 is effected by an electronic control unit (ECU) 41 which controls current supplied by a battery 42 according to signals supplied by a throttle potentiometer 43, indicating the engine load, rotational speed signals from transducers 44, 45, 46 and 47 used to measure the speeds of the crankshaft 13, the gearbox input shaft 14, the gearbox output shaft 21, and the auxiliary drive shaft 32 respectively. A torque transducer 48 is

used to measure the torque applied to the gearbox input shaft 14 through the drive clutch 12.

To demonstrate the effect of the invention, operation of the drive clutch 12 and the gearbox 11 will first be described without the electric motor 31 and the auxiliary clutches 35 and 36 in operation. First gear is engaged with the drive clutch 12 disengaged and the vehicle is set in motion by gradually engaging the drive clutch. The change from first gear to second gear is effected by disengaging the drive clutch 12, disengaging the synchromesh providing the drive through the first speed gear train 15, engaging the synchromesh selecting the second speed gear train 16 and re-engaging the drive clutch 12. This is the well-known procedure used in a manual gearbox with the drive clutch 12 under the direct control of the driver by a clutch pedal and automation of the clutch operation and the gearchange operation are both well-known. The problem with such an arrangement, as previously mentioned, is the interruption of drive to the wheels 26, 27 caused when the drive clutch 12 is disengaged for gear changes. This is particularly noticeable on heavily laden vehicles on steep slopes or on high-resistance off-road surfaces such a deep sand.

The problem is illustrated in the graph shown in Fig.2 which shows vehicle speed V (in meters/second) plotted against time t (in seconds) during a simulation of a vehicle travelling along at a steady speed in third gear until it encounters a steep gradient at A. As the vehicle slows, the driver attempts to change down to second gear at B. To do this, the driver has to depress the clutch thereby breaking the driveline torque and causing the vehicle to slow down rapidly. By the time the torque is re-applied at C the vehicle speed is such that second gear is no longer appropriate, the engine speed being so low that it is difficult to accelerate the vehicle back to the speed available from the new gear ratio.

In the present invention, the electric motor 31 is used in conjunction with the first auxiliary clutch 35 in a manner which alleviates the above problem. As before, starting off from rest is achieved by engaging first gear with the drive clutch 12 disengaged and the vehicle is set in motion by gradually engaging the drive clutch. As before, the change from first gear to second gear is effected by disengaging the drive clutch 12, disengaging the synchromesh of the first speed gear train 15, engaging the synchromesh selecting the second speed gear train 16 and re-engaging the drive clutch 12. However, while the drive clutch 12 is being disengaged, the first auxiliary clutch 35 is engaged to apply drive from the electric motor through the auxiliary gear train 34 to the gearbox output shaft 21. The ECU 41 controls the output of the electric motor 31 so that the torque delivered to the driving wheels 26, 27 is interrupted to a minimal extent. In practice, this will mean that the torque of the electric motor 31 will initially rise to match the power output of the engine 10 but will decay to match the power required for the new gear ratio before falling off completely as the drive clutch 12 re-engages.

In the graph shown in Fig.3 a gearbox up-change as described above is plotted as a graph of gearbox output torque T against time t. The torque derived from the engine 10 is shown as T_I and the torque derived from the electric motor 31 is shown as T_E. The total torque T_S is the sum of the engine derived torque T_I and the electric motor derived torque T_E and this, and hence the power transmitted to the road wheels 26, 27, is continuous throughout the gear change.

The invention may be applied to downward gearchanges as well as upward gear changes and the gear change sequence will be similar to that described with respect to the upchange from first to second.

The energy ordinarily dissipated in the drive clutch 12 when the vehicle moves off from rest is very considerable if the vehicle is on a steep hill, particularly

when repeated starts are made. This usually results in rapid heating of the drive clutch 12 and high wear. To minimise the amount of energy generated in the drive clutch 12, the ECU 41 is operable to engage the second auxiliary clutch 35 and the electric motor 31 for a short period of time during starting-off from rest. This reduces the torque which the drive clutch 12 is required to transmit and thereby the energy which it is required to dissipate. If necessary, the electric motor 13 can be operated until the speed differential across the clutch 11 is substantially zero or until a pre-determined speed difference is reached. It will be appreciated that the first auxiliary clutch 35 could be engaged for such assistance so that the second auxiliary clutch 36 may be optional. However, in most arrangements of gearbox, the gear ratio obtained when the electric motor drives the gearbox input shaft 14 through the second auxiliary clutch 36 will mean that a greater assisting torque is available in the arrangement described.

The second auxiliary clutch 36 may be used to adjust the speed of the gearbox input shaft 14 during a gear change and thereby reduce the work performed by the synchromesh clutches or allow them to be replaced by simpler dog clutches. Instead of one electric motor 31, there may be two electric motors each driving the appropriate auxiliary clutch 35 or 36 or directly coupled to the appropriate gearbox input or output shaft 14 or 21.

If required, the electric motor 31 can be used at other times, either to assist the engine 10 or as the sole means of propulsion, e.g. in heavy traffic or urban conditions to minimise emissions. Under such circumstances, the electric motor 31 would drive through the most appropriate auxiliary clutch 35 or 36 according to road speed and power requirements.

In a modification (not shown) the ECU 41 is also connected to an anti-lock braking system controller and to an accelerator pedal sensor. On low friction

surfaces such as ice, a sudden change in the supply of torque from the engine 10 to the driving wheels 26, 27 such as produced when going from a driving state to an overrun state can result in locking of one or more of the driven wheels even though no braking force is being applied from the braking system of the motor vehicle. To reduce the risk of this happening, the ECU 41 is signalled by the anti-lock controller to cause the electric motor to supply a small amount of driving power through the appropriate auxiliary clutch 35 or 36 to prevent locking since this can be a more responsive means of applying driving torque than increasing the engine power output.

It will be appreciated that as well as the second auxiliary clutch 36 being optional as mentioned above, the electric motor 31 could be arranged to drive the gearbox output shaft 21 direct. However, this would be at the expense of additional wear of the motor 31.

The invention may be applied to other gearboxes with different arrangements of gears and shafts and more or less than four forward ratios.

CLAIMS

1. A motor vehicle having an engine, a transmission system to transmit drive from the engine to one or more driven road wheels and a drive clutch interposed between the engine and the transmission system to selectively engage drive therebetween, the transmission system having a multi-speed gearbox including constant mesh gear trains each comprising a pair of gears, one gear of each pair being mounted on a driving shaft and the other of each pair being mounted a driven shaft to provide a number of gearbox ratios, the driving shaft being operatively connected to the drive clutch and the driven shaft being operatively connected to the or each road wheel, the motor vehicle further comprising an electric motor drivably connected to the driven shaft to provide a driving effort to the transmission system at least when the gearbox is changing gear so as to provide a continuous supply of power to the or each driven road wheel.

2. A motor vehicle as claimed in claim 1 in which the electric motor is selectively connected to the driven shaft by a first auxiliary clutch.

3. A motor vehicle as claimed in claim 1 or in claim 2 in which the electric motor is selectively connected to the driving shaft by a second auxiliary clutch.

4. A motor vehicle as claimed in claim 2 or claim 3 in which the electric motor is connected to the first auxiliary clutch by an auxiliary gear train.

5. A motor vehicle as claimed in any preceding claim in which the electric motor is arranged to provide a driving effort to the or each driving wheel when the motor vehicle is starting from rest to assist with engagement of the drive clutch.

6. A motor vehicle as claimed in claim 5 when dependent upon claim 3 in which the electric motor is arranged to provide a driving effort to the or each driving wheel when the motor vehicle is starting from rest to assist with engagement of the drive clutch when the electric motor is connected to the driving shaft by the second auxiliary clutch..

7. A motor vehicle as claimed in any preceding claim in which an anti-lock braking system is provided to prevent skidding of the road wheels and the electric motor is used to supply additional power to the or each driven road wheel in the event of wheel lock being sensed.

8. A motor vehicle substantially as described herein with reference to the Fig. 1 of the accompanying drawings.

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Application No:	GB 9901660.2	**Examiner:**	Tom Sutherland
Claims searched:	1 - 7	**Date of search:**	5 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): B7H (HDE), F2D (DCA)

Int Cl (Ed.6): B60K 41/00, 6/04

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	WO 98/31559 A	(ROVER) Whole document relevant.	1
X	US 5713425	(FORD) Note column 4 lines 1 to 8.	1 and 5

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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